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L. O. HOWARD, Entomologist and Chief of Bureau.

THE MEDITERRANEAN FRUIT-FLY.

BY

A. L. QUAINTANCE,

In Charge of Deciduous Fruit Insect Investigations.

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DECIDUOUS FRUIT INSECT INVESTIGATIONS.

A. L. QUAINTANCE, *in charge.*

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J. F. ZIMMER, W. S. ABBOTT, W. H. SILL, *entomological assistants, employed in enforcement of insecticide act, 1910.*

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United States Department of Agriculture,

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L. O. HOWARD, Entomologist and Chief of Bureau.

THE MEDITERRANEAN FRUIT-FLY.

(*Ceratitis capitata* Wiedemann.)

By A. L. QUAINTANCE,

In Charge of Deciduous Fruit Insect Investigations.

INTRODUCTION.

The recent establishment in Hawaii of the Mediterranean fruit-fly (fig. 1) and the quarantine restrictions against Hawaiian fruit imposed by the State of California have aroused considerable inter-

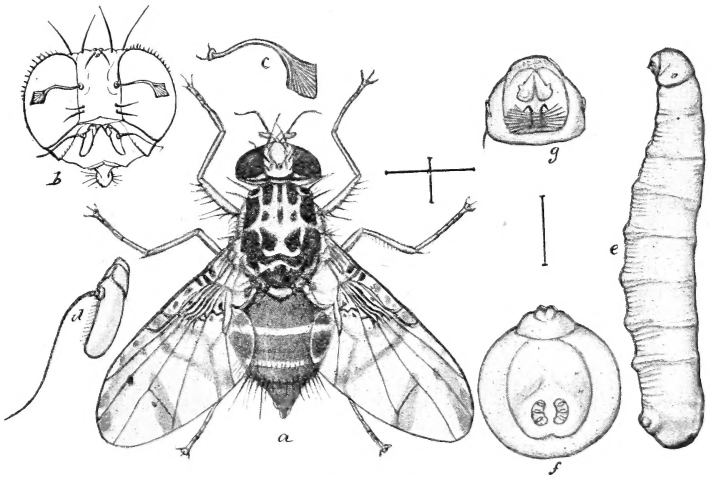

FIG. 1.—The Mediterranean fruit-fly (*Ceratitis capitata*): *a*, Adult fly; *b*, head of same from front; *c*, spatula-like hair from face of male; *d*, antenna; *e*, larva; *f*, anal segment of same; *g*, head of same. *a* and *e*, enlarged; *b*, *g*, *f*, greatly enlarged; *c*, *d*, still more greatly enlarged. (From Howard.)

est in this very destructive insect, and there have been frequent requests for information concerning it. To meet this demand for information the present paper has been prepared and largely com-

piled from the writings of entomologists in countries where the insect exists, particularly the writings of Froggatt, French, and Fuller in Australia, and Lounsbury and Mally in Cape Colony, South Africa.

There can be no question that the Mediterranean fruit-fly is a most serious drawback to the successful cultivation of fruit in the countries where it is established. Indeed, the cultivation of fruits is scarcely possible in the worst infested regions. The fruit-growing industry of Bermuda was practically destroyed many years ago by the introduction of the insect into that island. Its introduction into the United States in all probability would be calamitous to the orchard interests of our more southern States and of California, in which regions it would find conditions very similar to those in countries where it now exists in most destructive numbers.

This species belongs to a group of insects—the family Trypetidæ of the order Diptera, or flies—for which no very successful means of control have been found. Despite a large amount of experimentation in the control of this as well as other related species, including our own apple maggot or railroad worm (*Rhagoletis pomonella* Walsh), little has been developed that is of value in lessening their injury, except the collection and destruction of fallen infested fruit and the more recent use in South Africa of a poisoned bait sprayed over the trees for the destruction of the adult flies.

In view of the very serious character of the pest and the great difficulty in its control, it is most urgent that all possible pains should be taken to prevent its introduction into this country. The energetic measures taken by the Hawaiian and California authorities are much to be commended.

COMMON AND SCIENTIFIC NAMES.

The name "Mediterranean fruit-fly" was first given to this insect by Froggatt, who believed that the insect had probably been introduced into Australia from the region of the Mediterranean. It has, however, been given numerous other common names, as the peach fly, peach maggot, etc. The species has been twice redescribed since first characterized by Wiedmann in 1824, and the synonymy stands as follows:

1824. *Tephritis capitata* Wiedemann, Analecta Entomologica, p. 55.
1829. *Ceratitis citriperda* Macleay, Zoological Journal, vol. 4, p. 475.
1842. *Ceratitis hispanica* de Brême, Annales de la Société Entomologique de France, vol. 11, p. 183.

Some authors also consider *Ceratitis cattoirei* Guérin as identical with or a mere variety of *capitata*.

The species has been variously referred by authors to the genera Tephritis, Trypeta, Ceratitis, Petalophora, Halterophora, etc., but Ceratitis appears to be the latest reference.

HISTORY AND DISTRIBUTION.

The Mediterranean fruit-fly was originally described by Wiedemann under the name *Trypeta capitata*, from specimens said to have come from the East Indies.

Latreille in Cuvier's Régne Animal, published in 1817, under the caption " Les Tephrites " states, on the authority of Cattoire, that the colonists of the Isle of France (Mauritius) were scarcely able to obtain sound citrus fruits, perfect at maturity, on account of the extreme abundance of a dipterous insect which deposited eggs in them. This early reference might be considered as referring to the Mediterranean fruit-fly. A specimen, presumably this same insect, was sent by Cattoire to Macleay, who so regarded it, but it was later given specific rank by Guérin under the name *Ceratitis cattoirei*.

Although the insect was described by Wiedemann, it was first brought prominently into notice by Macleay in 1829, in an article published in the Zoological Journal (vol. 4, p. 475) entitled " Notice of *Ceratitis citriperda*, an insect very destructive to orange." Macleay's article, accompanied by a colored plate, was based on specimens obtained from the Azores. Shipments of oranges from these islands were reaching the London market in bad condition and, as stated by Macleay, of the quantity annually received, from 90,000 to 100,000 chests, about one-third were thus affected. Not infrequently whole cargoes were in such a state of decay as not to bring the value of the freight. This breaking down of the fruit en route, while possibly due in part to other causes, was attributed by Macleay to the ravages of this insect. Macleay also made note of its occurrence on the island of St. Michael, where it was especially troublesome during March, April, and May. In a footnote to his article he adds that the perfect fly was observed by him on a heap of oranges in the market place of Funchal, island of Madeira, and also at St. Jago, Cape Verde Islands, and calls attention to a report that a maggot infests oranges in the West Indies.

Wiedemann (Aussereurop. Zweiflüg. Insekten, p. 496) in 1830 again describes the insect under the name *Trypeta capitata*, citing his earlier description (Analecta Entomologica, p. 55, Nr. 124), and adds: "A queer little animal which was placed in the Royal Museum with the name *Musca capitata*, with the information that it had been captured by Daldorf on the Indian Ocean." The type is said to be in the Royal Museum at Copenhagen.

F. de Brême, in the Annales de la Société Entomologique de France for 1842, redescribes the Mediterranean fruit-fly under the name of *Ceratitis hispanica*, from specimens found in oranges in the environs of Malaga, Spain. He points out supposed differences between his species and that of Macleay.

In the Gardeners' Chronicle for September, 1848, Westwood, under the caption "The orange fly," refers to Macleay's article and records receiving wormy oranges from a Botolph Lane merchant, from which material he drew up a description of the maggot and pupa. The specimens were from St. Michael Island, and Westwood remarks that the insect is also native of "St. Jago and the Cape Verde Islands" and adds that he has long possessed specimens of this fly taken "on the wing in Thames Street."

At the meeting of the Société Entomologique de France, January 26, 1859, Villeneuve exhibited an orange received by him from Algeria and infested with a dipterous maggot. From this fruit the adult fly was reared and was recognized by him as *Ceratitis hispanica*, as later reported to the society at its session of March 23, 1859.

As stated by Prof. C. Rondani (Bull. Ent. Soc. Ital., p. 29, 1870) the species is rare in Spain, and he adds that it is found only in southern Italy.

In 1871, under the title "Dommages causés par la *Ceratitis hispanica*," Laboulbène (Annales de la Société Entomologique de France, p. 439) describes the injuries caused by the fruit-fly to oranges in Algeria and presents a detailed description of the species prepared by J. Bigot. He quotes notes furnished him by Boisduval to the effect that at Blidah and in all Algeria the orange crop was completely destroyed by the insect.

In The Entomologist's Monthly Magazine for 1884 (p. 34) Osten-Sacken lists the Mediterranean fruit-fly under the name of *Ceratitis capitata*, referring to its occurrence in the Madeira Islands, and adds that it attacks oranges wherever they grow. He also states that *C. citriperda* Macleay and *C. hispanica* de Brême are mere synonyms, or species based on individual varieties.

Röder, in the Berliner Entomologische Zeitschrift for 1885 (p. 132), in an article "Ueber die Dipteren Gattung, Ceratitis Macleay," gives the synonymy of *Ceratitis capitata*, and also its distribution as follows: Southern Spain, southern Italy, Algeria, Tunis, Madeira, Mauritius, Indian Ocean, Kongo, Cape Coast, Delagoa Bay.

Penzig, in the Annali de Agricultura for 1887, presents an extended account of the diseases and insect enemies of the orange and treats at length of the dipterous pests of the fruit, referring to three species of Ceratitis under the generic name Halterophora. The species considered, namely, *capitata*, *cattoirei*, and *hispanica*, are by him considered identical. Extended life-history notes are given and the orange is stated to be the principal fruit infested, but lemons and other cultivated citrus fruits are attacked, as well as peaches, figs, azaroles, etc. The species is thought to be limited to the country around the Mediterranean and its injuries in Algeria are noted. In Sicily oranges were first attacked and later peaches. In Liguria it

was noted as injurious to peaches in 1882, but little, if at all, attacking citrus fruits.

As stated by Girard, the Mediterranean fruit-fly became established in the environs of Paris, infesting apricots at Courbevoie. In a further note on the subject (Compt. Rend., Aug. 20, 1906) M. Girard reports that the insect has insidiously increased its ravages, and at that time peaches were seriously affected in many localities around Paris. According to Prof. Paul Marchal, however, the pest was not troublesome the year following (1907), for which reason it is thought the insect did not become properly established.

An account of this species, under the name of the Bermuda peach maggot, is given by Riley and Howard in Insect Life (vol. 3, p. 5), which appeared in 1890. The insect was reared at the insectary in Washington from peaches received from Claud W. McCallan, of St. Georges, Bermuda. In further correspondence with Mr. McCallan it was learned that peaches had been more or less infested for about 25 years and their culture had practically to be abandoned. It is stated that oranges are little attacked on the island, but that the maggots infest the Surinam cherry (*Eugenia michelii*), half of the crop being ruined annually. The loquat (*Eriobotrya japonica*) and the Malta plum are also subject to infestation, as well as the bitter Seville orange. Mr. McCallan has expressed the opinion that the insect made its appearance in the island in a cargo of fruit from the Mediterranean region, which, while intended for the American market, was landed at the island through stress of bad weather.

Miss Ormerod, in her publication, "Injurious Farm and Fruit Insects of South Africa," which appeared in 1889, gives an account of the injuries done by the fruit-fly in Cape Colony. This is apparently the first reference to the occurrence of the pest in that region, although, as noted by Mally, it was introduced many years before this date.

Apparently Mr. Claude Fuller was first to record the occurrence in Australia of *Ceratitis capitata*, the record appearing in the Journal of the Bureau of Agriculture of West Australia for February, 1897. In the March number of the same journal Mr. Fuller gives information concerning the life history of the insect, together with a good plate. At about the same time Mr. H. Tryon received specimens from West Australia, and the year following it was reared by Mr. C. French from peaches imported into Victoria from Sydney. The fly was discovered a few days later by Mr. W. W. Froggatt in rearing jars containing fruit supposed to have been infested with the Queensland fruit-fly. It is thought to have made its way into Australia in oranges from Italy, a considerable quantity of which at that time was being imported.

Though the fruit-fly was also common at about that period in South African oranges, the above facts are considered good evidence by Froggatt that it was introduced into Australia from European countries, and hence the popular name "Mediterranean fruit-fly," by which the species was designated by him. Concerning its distribution in Australia Froggatt states:

> This fly has spread all through the citrous orchards of New South Wales, to a greater or less extent, but until a few years ago was unknown in the southern parts of this State and the adjoining State of Victoria. At the present time, however, it is found in orchards at Albury, N. S. W., and in quite a number of Victoria orchards, where it has become more or less established.

The insect is also present in Queensland, as specimens have been obtained from Brisbane. In West Australia, in the vicinity of Perth and all through the citrus orchards, it is regarded as a great pest to fruit growing, as in the climate of New South Wales.

Although the species has probably several times been introduced into Tasmania, it has apparently not yet gained a foothold there. In New Zealand the fly has also been frequently introduced, and at one time was established to a certain extent in the vicinity of Napier. Its future development in the island, however, was considered problematical by some in view of the character of the climate. As pointed out by Mr. T. W. Kirk, however, there appears to be no reason why the insect would not be equally at home in New Zealand as in Australia.

The time of its introduction into South Africa is not definitely known. It is thought to have been brought in with fruit from Madeira. Writing in 1904, C. W. Mally states that it is not difficult to find men who are familiar with the depredations of this insect in the coastal belt of the colony 30 years ago. It is now generally present in the fruit-growing regions of Cape Colony and is recorded from Natal. According to Mr. C. W. Howard it is also present in the Transvaal, and in Uganda, as recorded by Gowdey: in northern Egypt (Cairo), as stated by Froggatt; and at Kafrez-Zaiyat, also in Egypt, on the authority of Cartwright. Mr. Geo. Compere, who has traveled in many parts of the world in connection with his search for parasitic and predatory enemies of destructive insects, states that the Mediterranean fruit-fly is present in Asiatic Turkey, St. Helena Island, at Valencia (Eastern Spain), and in Bahia and Sao Paulo, in Eastern Brazil.

This fruit-fly was discovered in Hawaii about the middle of the year 1910, and the fact of its establishment in the island of Oahu was announced to the Board of Commissioners of Agriculture and Forestry by the entomologist, Mr. E. M. Ehrhorn, at its meeting on October 5 of that year. It was suggested by Mr. Ehrhorn, and the suggestion was promptly carried out, that notice be given to the Cali-

fornia State Horticultural Commission of the establishment of the pest in the island. General observations indicate that the insect had been present in the island some two or three years previous to its discovery. It was first reared from oranges taken in Honolulu. The Territorial Board of Agriculture and Forestry promulgated a regulation (rule 7), which was signed by the governor November 21, 1910, prohibiting the shipment of fruits subject to infestation to other islands of the territory.

The California Horticultural Commission, upon notification of the occurrence in Hawaii of the Mediterranean fruit-fly, promptly adopted rigid inspection of fruits and vegetables received at San Francisco. As a result infested fruits were frequently found, and June 24, 1911, a quarantine order against Hawaii was issued barring "* * * the importation of all fruits, vegetables, berries, seed pods, etc., either cultivated in the orchards or gardens or growing wild in the Hawaiian Islands, with the exception that pineapples, bananas, and all root crops the edible portions of which during growth have always been beneath the surface of the soil shall be admitted at the ports of the State of California after having been duly inspected: *Provided*, That any or all of these exempted fruits or vegetables, if at any time hereafter shall be found to contain upon inspection the egg, larvæ, or pupæ of the fruit-fly (*Ceratitis capitata*), they shall be immediately included in the list of quarantined fruits and vegetables."[1]

During the summer of 1911 Mr. E. K. Carnes visited Hawaii and spent some time in a thorough investigation of fruit-fly conditions and gave a preliminary report of his investigation in the monthly bulletin of the State Commission of Horticulture of California for December, 1911, pages 5–13. The substance of this report later appeared in the Proceedings of the Fortieth Fruit Growers' Convention of the State of California, pages 71–78. In December, 1911, Commissioner A. J. Cook dispatched to the island as a port inspector to assist in preventing embarkation of infested fruit Mr. H. A. Weinland, working in conjunction with Mr. Ehrhorn, superintendent of entomology, and Mr. W. M. Giffard, director of the fruit-fly control. The plan of work adopted by the Hawaiian authorities has been in the main that of eradication. The difficulties of the situation are, however, enormous by reason of the irregular nature of the country and the large list of fruits upon which the insect may subsist. This situation is well pointed out by Carnes in his report in the Proceedings of the Fortieth Fruit Growers' Convention of the State of California, page 74, as follows:

From the best authentic information available, it appears that the Mediterranean fruit-fly has been on the Island of Oahu, upon which the city of Honolulu

[1] Horticultural statutes of the State of California, 1912, p. 26. (Sacramento, 1912.)

is located, for at least two years and probably longer. It is now firmly established in practically all sections of this island and it has also been taken on the adjacent island of Kauai, known as the Garden Island. I did not find it on the Island of Maui, but, owing to the limited time assigned to my investigation, to cover the entire territory was impossible; moreover, the realization came to me that our real problem was the Island of Oahu. * * *

The fly has spread from the lower cultivated areas and is now infesting the wild guavas on the sides of the mountain, in the gulches, on the plains, and in the cultivated portions of the valleys. In addition to the wild guavas, which are almost continually in fruit, many other wild fruits that are hosts grow in abundance; also, large patches of the prickly-pear cactus are to be found all over the mountains. In other countries this fruit carries the flies over winter, and will undoubtedly prove a host fruit in the absence of other hosts.

The worst infested portion of the Island of Oahu is the resident section of the city of Honolulu, and it is from this plague spot that California would be most likely to become infested. This is the section visited by all tourists stopping at Honolulu, and it is from this district that they procure the tropical fruit which finds its way to the port of San Francisco.

The very dangerous character of the pest led Congress to make an emergency appropriation for an investigation of the insect in the United States, its territories and possessions, and this work will be promptly taken up by the Bureau of Entomology.[1]

The published records indicate that the Mediterranean fruit-fly is widely distributed in tropical and subtropical parts of the world. It is recorded from the following countries:

Algeria, Asiatic Turkey, the Azores, Brazil (Rio de Janeiro, Sao Paulo), Bermuda, Cape Verde Islands, East Indies, Egypt (Cairo, Kafrez-Zaiyat), France, Madeira Islands, Malta, Mauritius, Natal, New South Wales, New Zealand, Queensland, St. Helena Island, Sicily, Spain (Malaga, Valencia, Barcelona), South Africa, Tasmania, Transvaal, Uganda, Victoria, and West Australia.

Considering the insect in connection with its known distribution and destructiveness, it appears fairly certain that it would not be able to maintain itself in regions where the temperature during winter falls much below the freezing point. The failure of the insect to extend its range northward from the Mediterranean region seems to warrant this conclusion. There is, however, much territory in the United States where the pest would doubtless thrive, as in our more southern States and in California.

FOOD PLANTS AND DESTRUCTIVENESS.

The very destructive character of the Mediterranean fruit-fly has been evident since the insect first came prominently into notice in 1829. Its injuries to citrus fruits, especially the orange, were early complained of, and as the insect has spread the list of fruits attacked

[1] August 20, 1912, an act was passed by Congress and approved by the President which enables the Secretary of Agriculture to establish and maintain quarantine against dangerously injurious insect pests and plant diseases. The necessary steps are being taken for the purpose of promulgating a quarantine to prevent the introduction of the Mediterranean fruit-fly.

has materially increased. As already noted, its injuries to oranges in the Mediterranean region, as well as in the Madeira Islands, the Azores, etc., have largely interfered with the successful culture of these crops. Upon its introduction into South Africa it soon gained a foothold, and became a pest of first-class importance, and its behavior since its establishment in Australia has been even more disastrous to the fruit growers. Concerning its injuries in Cape Colony Mr. Chas. P. Lounsbury, Government entomologist, writing in 1907, says:

From the horticultural standpoint, the peach maggot (*Ceratitis capitata*) ranks first in importance among injurious insects of the past season. This pest is always one which attracts much attention, and its ravages this year have been greater than usual. It survives the winter as a mature insect and becomes more and more numerous as the season advances, there being a succession of broods. December apricots were much infested this year, and in most parts of the Western Provinces late peaches and nectarines were almost all maggotty. Other deciduous fruits suffered to a lesser extent. At the date of writing, infested guavas are not uncommon, and numerous flies may be found in most orange groves; only a small percentage of the fruit of the orange, however, is attacked in this vicinity. In the eastern parts of the colony the ravages of the pest are more severe. Oranges are there more subject to it, and in some groves most of the fruit is said to be spoiled. Late peaches are said to be almost unobtainable, and I have myself seen nearly half the loquats on a large tree in full bearing infested by this pernicious pest at Grahamstown. Loquats, however, do not seem to be generally attacked, and I have heard of no occurrence of this kind in the western fruit-growing sections of the colony. The destruction of infested fallen fruit is practised by some of the most enterprising fruit growers. The utility of this course is questioned by some who have adopted it, but from personal observation I am inclined to believe that the trouble lies in lack of thoroughness; too often a tree in some odd corner is not visited or some worthless fruit is allowed to remain on the trees after the crop has been gathered.

In the Journal of Agriculture, May, 1897, Mr. C. French, then Government entomologist of Victoria, states:

This terrible scourge of the fruit grower is becoming but too familiar in Victoria, larvæ having been found in peaches, pears, quinces, apricots, plums, nectarines, guavas, oranges, lemons, apples, citrons, loquats, mangoes, pumpkins, bananas, tomatoes, pineapples and persimmons; so that it will easily be seen that hardly any fruit can be said to be exempt from its attacks and of all the fruit grower's enemies, the fruit-fly is undoubtedly the worst.

In Bulletin 22 of the New Zealand Department of Agriculture (1909), Mr. T. W. Kirk, writing of the Mediterranean fruit-fly, states:

We have now had to burn consignments of the following fruits because they were infested with this dreaded maggot: Peaches, apricots, nectarines, cherries, pears, apples, mangoes, shaddocks, mammee-apples, pineapples, tomatoes, loquats, persimmons, plums, mandarins, oranges, bananas, maupi fruit, grenadillas, figs.

Should this pest ever become established here it will mean the ruin of the stone-fruit industry of the North. It will be seen that practically all varieties of fruit are attacked, and the measures taken to keep this fly out of New Zealand can not be too severe.

Mr. C. W. Mally, entomologist for the Eastern Province, Cape of Good Hope, South Africa, in the Agricultural Journal, December, 1904, states:

It is difficult to say from whence the fruit fly came. It was most likely brought to the Cape in fruit from Madeira. How long ago no one can tell! It is not difficult to find men who were familiar with the depredations of this insect in the coastal belt of the Colony thirty years ago. Until recently the Mediterranean regions were looked upon as the original home of this species, mainly because it had been known to be injurious there for such a long time. If the presence of natural enemies is a safe guide, Mr. Geo. Compere's discovery, that this pest is kept under almost complete control in Brazil through the agency of natural enemies, would point to that country as the original home. Be that as it may, we are all well aware that the fly has become a constant factor in fruit-growing in Cape Colony. How to prevent its injuries is the demand that has necessitated investigation with a view to establishing the practicability of control measures. The first step is to determine the insects.

Mr. Geo. Compere, of the California Horticultural Commission, writing of fruit-flies in the Proceedings of the Thirty-eighth Fruit Growers' Convention, remarks:

The next species that I wish to call your attention to is *Ceratitis capitata*, Wied., or, commonly called, the Mediterranean fruit fly. With this species I have had more experience than with any of the other forms, and I can say that it is without question the most destructive fruit pest on record in the world to-day. Not that it is any more destructive to any particular variety of fruit than many of the other species of this group of flies, but it is so, from the extremely wide range of food fruits. While most of the species confine themselves to one or a few varieties of fruits, this one will attack every known fruit with the exception of the banana, pineapple, and olive. It flourishes in the bitterest of limes and bitter orange the same as it does in the most delicious peach, pear, or apple.

Writing of the fruit-fly in Hawaii, Mr. E. K. Carnes, as a result of a visit to the islands under the auspices of the California State Commission of Horticulture, states:

On Oahu the following fruits and vegetables have been attacked: All species of citrus fruit, peaches, figs, grapes, rose apple, star apple, mangoes, white lemon guavas, wild guavas, alligator pears (bruised and fallen), strawberry guavas, papaya, sapota, *Carissa arduina* (South African), also string beans and peppers.

In addition to this list the known host fruits include: Eggplant, coffee, plums, cherries, persimmons, grenadillas, maupi fruit, apricots, pears, nectarines, loquats, apples, shaddocks, mandarins, mammee-apples.

So far the banana and pineapple appear to be immune from attack, but close inspection should be maintained for future development.

To this list for Hawaii should be added the additional fruits more recently found to be infested, as stated by Mr. W. M. Giffard (Hawaiian Forester and Agriculturist, April, 1912), namely: Kumquat (*Citrus japonica*), *Murraya exotica*, and *Eugenia* sp. Mr. Giffard adds:

I would further report that coffee berries, varieties of orange, loquats, varieties of Eugenia, and Kamani seeds appear to be among the worst-infested fruits so far examined.

The above records indicate the omnivorous character of the pest and leave no doubt that when once introduced into a locality where proper temperature conditions exist it will be able to maintain itself without difficulty. Its life history in Bermuda, as stated by T. I. Harris, director of the public gardens, in the Bermuda Colonist for the 12th of August, 1907, may be quoted in this connection. It will be recalled that the pest was introduced into Bermuda many years ago:

Though the great variety of fruiting trees growing here is insufficient to furnish propagating media for flies throughout the whole year, each successive generation making use of a different kind of fruit, without doubt the Surinam cherry (*Eugenia michelii*) has been the most potent factor in perpetuating the pest. There are two main crops of fruit, one in the spring and another in the fall, but stragglers between each cause the two crops to overlap.

The loquats (*Eriobotrya japonica*), ripening in February and March, are used by the fruit flies of the year, from the puparia that have lived dormant in the ground during the two coldest months, and the larvæ hatched from the eggs of these flies begin to pupate before the loquats are all over. In some instances this year, where the fruit had been pecked by birds and had shrivelled on the trees, complete pupæ were found within the fruit. At the end of April and during May, the peach, cherry, oranges (both sweet and sour), lemons and limes, Barbados gooseberry, and capsicums bring forth another crop of maggots that, after pupation, are just in time for the sapodillas in June and July. Following these are the mangoes, coffee, sweet peppers, cherries again, avocado pears, guavas, sugar apples, cherimoyas, quinces, cocoa-plum, grenadillas, and star apples, which serve as propagating media until the final resting brood goes to earth during December.

While the general feeding habits of the fruit-fly render a complete list of fruits attacked of secondary importance, yet it is desirable to know from what fruit it has actually been reared, or which have been noted as infested.

The evidence of infestation in the case of bananas is not as conclusive as is desirable, especially as to whether the fruit in a green condition as gathered for shipment is infested. As recorded by French (Journ. Agr., 1907, p. 302) the larvæ of this fly were found in bananas imported from Queensland, on August 14, 1906, and the perfect insect reared. The same author, in his Hand Book of the Destructive Insects of Victoria (vol. 4, p. 35), says:

It has been frequently stated in Queensland and New South Wales, that the flies will not attack green fruit. This is a mistake, as I have on many occasions proved eggs to have been deposited in green bananas before shipment, as no half-ripe bananas are ever shipped from Queensland to Melbourne.

On the other hand, the Hawaiian entomologists have not found the insect attacking bananas, and believe that in the green condition in which it is gathered the fruit is not subject to attack. Ripe bananas are, however, unquestionably infested.

Both Mr. French and Mr. Kirk record finding larvæ of the Mediterranean fruit-fly in pineapples.

A list is given below of all fruits recorded in literature, so far as we have been able to determine, which are subject to infestation by the Mediterranean fruit-fly.

FRUITS INFESTED BY THE MEDITERRANEAN FRUIT-FLY.[1]

Aberia caffra (Kei apple).
Alligator pear.
Almonds (?).
Anona.
Apple.
Apricot.
Atropa belladona (nightshade).
Avocado pear.
Azarole.
Banana.
Barbados gooseberry.
Beans (string).
Capsicum.
Carambola (Averrhoa).
Carica quercifolia; baby papaya.
Carissa arduina.
Cherimoya (*Anona cherimolia*)
Cherry.
Chinese ink berry (*Cestrum* sp.).
Chinese plum (*Horonhia emarginata*).
Chrysophyllum cainito (star apple).
Citron.
Citrus fruits, all kinds.
Citrus buxifolius.
Citrus japonica (Kumquat).
Cocoa-plum (*Chrysobalanus icaco*).
Coffee berry.
Eggplant.
Eugenia jambos (rose apple).
Eugenia michelii (Surinam cherry).
Fig.
Grenadilla.
Grape (?).
Grapefruit.
Guava (cultivated).
Guava (strawberry).
Guava (wild).
Harpephyllum caffrum (Kaffir plum).
Kaffir plum (*Harpephyllum caffrum*).
Kei apple (*Aberia caffra*).
"Kamani" seeds.
Kumquat (*Citrus japonica*).
Lemon.
Lime.
Loquat (*Eriobotrya japonica*).
Mammee-apples (*Mammea americana*).
Mandarin.
Mango.
Maupi fruit.
Mountain apple.
Murraya exotica (mock orange).
Nectarine.
Nightshade (*Atropa belladona*).
Opuntia vulgaris (prickly pear).
Opuntia tuna.
Orange.
Papaya (baby).
Papaya (over-ripe).
Passion flower (*Passiflora cærulea*).
Passion fruit.
Peach.
Pear.
Pepper, sweet.
Pepper, green.
Persimmon.
Pineapple.
Plaquemine.
Plum.
Pompelmoes.
Prickly pear (*Opuntia vulgaris*).
Pumpkin.
Quince.
Rose apple (*Eugenia jambos*).
Shaddock.
Sapodilla (*Achras sapota*).
Sapota.
Solanum capsicastrum (cherry solanum).
Star apple.
Sugar apple.
Surinam cherry (*Eugenia michelii*).
Tomato.

[1] The names in this list are recorded exactly as they appear in the literature consulted. Since this literature is derived from various sources, chiefly from Hawaii, South Africa, and Australia, there is some repetition, owing to colloquialisms.

LIFE HISTORY AND HABITS.

The life history and habits of the Mediterranean fruit fly have been very carefully investigated by different entomologists, particularly by Froggatt, French, Mally, and others. The following account of the insect by C. W. Mally, entomologist for the Eastern Province, is quoted from his article on "The Fruit Fly," which appeared in the Agricultural Journal, Cape of Good Hope, December, 1904:

Aside from an occasional query, nothing is heard of the fruit fly till the maggots are abundant in the apricots and peaches. These maggots come from eggs deposited by the adult fly.

The eggs.—The female is provided with a sharp extensile ovipositor (the organ through which the eggs are laid) which enables her to pierce the fruit and at the same time deposit the small glistening white eggs just underneath the skin—sometimes singly but usually a number together. They hatch in a very short time, two to four days in midsummer. The ripeness of the fruit seems to influence the rapidity of their development. It is difficult to get reliable information on this point, for the mere fact that a fly is seen to pierce the fruit is no proof that eggs are left at the same time. By opening the fruit to make sure that eggs were deposited they are placed under unnatural conditions. Different lots of eggs may be laid in the same puncture. I have observed females in the act of oviposition and on immediate examination the pulp was found to be discoloured and as high as ten eggs present, in some of which the body segments of the larvæ were distinctly visible under the microscope. Although females may take advantage of slight injuries in the fruit they are by no means dependent upon them, and evidently prefer sound fruit in which to oviposit. Numerous examinations of peaches, apples, lemons, oranges, and pompelmoes, show that all eggs laid in fruit that is too green perish as eggs, or, if they do hatch, the young larvæ perish almost at once. This is an important point, for many fruit-growers take a hopeless view, believing that the eggs may be laid in the fruit while it is still very young and lie dormant until the pulp is sufficiently ripe to serve as food for the larvæ. It is of practical importance to those who enclose their trees with netting, for it reduces the time the netting must be exposed to the weather. Last March (1904) many apples were received showing a slight depression, in the center of which was a small black speck. On close examination it was found to be due to the fruit fly having oviposited, but no development followed. The apples were still hard and the great mortality in the eggs, the shrivelled remains of which could still be found, was considered to be due to the fruit having been too green when oviposition took place. There was no trace of parasitism.

The larvæ or "maggots" at once begin to feed on the pulp of the fruit. In apricots they make straight for the center, the pulp evidently first ripening round the pip. In peaches and other fruits they are more inclined to work out in different directions from the point of oviposition, there being no distinct tendency to penetrate towards the center. When fully developed, which usually requires a fortnight or three weeks, they leave the fruit, which has as a rule fallen several days previously, and enter the ground, seldom going deeper than one inch, depending on the nature of the soil. Here they soon change to puparia, and remain for twelve days to three weeks, depending on the season. When the transformation to adult is complete the fly pushes through the end of the

puparium and works its way up through the soil. On reaching the surface the wings expand to full size, and in a short time the fly is ready to search for food. They are fond of the exuding juice of injured fruit. After mating they lay eggs and die, thus marking the end of one generation and the beginning of the next. The eggs are not all deposited at once. Just how long the impregnated female lives and continues to lay eggs under natural conditions is not known, but it is several weeks at least.

The number of broods in a year depends on circumstances of food supply and temperature. In midsummer, with abundant food, they develop more rapidly, one generation being complete in about twenty-eight days. Very ripe fruit seems to hasten their development. During the winter, at Grahamstown [Cape Colony, S. Africa], they require two months or more to complete their transformations. The puparium stage of the midwinter brood, recorded below, required thirty-five days in the rearing-box in the office at the ordinary seasonal temperature. The broods overlap to such a great extent that it is impossible to keep them separate in the field.

With the approach of winter, the females are able to survive several months under natural conditions if no suitable fruit is available for egg deposition. The late peaches furnish the last grand feast, about the first of April. The adults of this generation emerge early in May and can survive till the citrus fruits are sufficiently ripe to serve as food for the larvæ.

In this article Mr. Mally adds that the adults are keen feeders, taking readily to the juice exuding from the injured or decaying fruit, and some individuals have been found to feed on the honeydew from certain scale insects. It is the consensus of opinion that the insect is carried from one locality to another by means of infested fruit. When once introduced in a locality, however, there will be a natural spread or dissemination of the species, though the rate of dissemination has not been ascertained. This will doubtless vary with the climate in question, particularly with the strength and direction of the winds. Migrations will be stimulated by an insufficiency of food supply.

DESCRIPTION.

The following description of the adult is quoted from Farmers' Bulletin 24, Department of Agriculture of New South Wales, by W. W. Froggatt:

Size 4 to 5 mm., about the size of an average house-fly, but looking somewhat smaller when dead, because the body shrinks up beneath the thorax. General color, ochreous yellow, lighter on the sides of thorax and basal joints of the antennæ. The eyes of the usual reddish purple tint, with a blackish blotch in the center of the forehead, from which spring two stout black bristles, a fine fringe of similar bristles round the hind margin of the head, with some coarser ones curving round in front of the head between the eyes. The thickened basal joints of the antennæ pale yellow, the terminal segments black to the tips. The dorsal surface of the thorax convex, raised, and broadly rounded with the scutellum, the ground color creamy white to yellow, marbled with shiny black blotches forming an irregular mosaic pattern, the lighter portions clothed with very fine white bristles. These light-colored bristles more lightly scattered over the dark areas, and the whole bearing large stout black bristles thickest on the black surface.

In many of the pictures of this insect the black areas are drawn as if they were projecting bosses or knobs, but this is incorrect; the whole forms a regular rounded surface.

The wings are broad, semiopaque, with the extreme base blotched with ochreous or brownish yellow, with the rest of the basal area curiously marked with black, forming dark lines of the radiating nervures, with dark lines and spots between; beyond this is a broad irregular transverse ochreous band, slightly lined with black, blotched at the extremity; another similar shaped and colored blotch runs along inside but not in contact with the costal nervure, also blotched towards the extremity in the angular space. Between these bands is another shorter black band running parallel with the first transverse band.

The oval abdomen is clothed on the upper surface with fine, scattered black bristles, and has two rather broad transverse silvery white bands on the basal half of the body. The male differs from the female in being furnished with a pair of stalked appendages standing out in front of the head in a line with the front margin of the eyes, the extremities of which filaments are produced in spatulate appendages, black, finely striated, and diamond shaped.

The living fly is an active little creature, running about over the foliage or fruit on the trees, with its wings drooping down on the sides of the body. When disturbed it has a short flight, seldom flying more than a few yards at the most, and it often returns to the same spot. [See fig. 1.]

NATURAL ENEMIES.

Considerable attention has been given to the investigation of possible insect enemies of fruit-flies, though to date no effective natural check appears to have been found. Observations by Mr. George Compere, in Brazil, led him to believe that this insect along with several other species of fruit-flies was there kept in check by a staphylinid beetle preying upon the maggots; and that it was also held in check by two species of Ichneumon wasps. Both the parasitic and predatory enemies were introduced into West Australia. Mr. Compere concludes his report [1] upon the introduction work with the statement that with the establishment of these enemies in the State the pest will be reduced to harmless numbers.

The importance of Mr. Compere's announcement led the Cape Government and the Natal Government to dispatch their entomologists (Mr. Lounsbury and Mr. Fuller) to Brazil in search of these enemies, as set forth in the Agricultural Journal of the Cape of Good Hope for January, 1905. In the October number of the same journal (1905) Mr. Lounsbury presents his report upon the trip to Brazil, that of Mr. Fuller having been earlier given in the Natal Agricultural Journal, May 26, 1905.

Mr. Lounsbury reports the Mediterranean fruit-fly as a very severe pest in the States of Sao Paulo, Rio de Janeiro, and probably elsewhere in Brazil where peaches are grown. No trace of the staphylinid beetle could be found and it was presumed to be an enemy of

[1] Journ. Agr. Dept. W. Australia, August, 1904.

fruit-flies only under certain conditions. A small parasitic wasp (*Opiellus trimaculatus* Spin.) was reared from a related fruit-fly, *Anastrepha fratercula*, and maggots infesting small fruits showed a higher percentage of parasitism. Another small wasp was observed crawling over peaches and in one instance apparently ovipositing in the fruit and was suspected of being parasitic on fruit-flies. Attempts were proposed to determine if the Opiellus parasite would also attack the Mediterranean fruit-fly, though apparently without much hope, as Mr. Lounsbury concludes:

> Whilst there still appear these possibilities that fruit fly parasites exist in Brazil that might prove of some value against South African fruit flies, I no longer have any hope whatever that these parasites may be capable of holding our fruit flies in such close subjection that artificial measures to save orchard fruits will become materially less necessary than they are at present.

Mr. W. W. Froggatt, under the auspices of the Governments of New South Wales, Victoria, South Australia, and Queensland, spent a year (July, 1907, to July, 1908) in an investigation of entomological questions in foreign countries, and during his trip around the world particular attention was paid by him to the subject of insect control by parasitic and predatory insects, especially with reference to enemies of fruit flies (Report on Parasitic and Injurious Insects, Department of Agriculture, New South Wales, 1909). No reference is made in this report to the discovery of natural enemies of fruit-flies, and that no hope is felt in such work is shown by the following statement (p. 68):

> I consider, as do nearly all leading entomologists who have given the matter of fruit flies any attention, that it is very improbable that any internal parasite will ever make any impression on this pest in the case of commercial fruit, such as oranges, peaches, etc. In all cases where parasites have been bred it has been from small, wild, or hard-fleshed fruits, and though parasites may be quite numerous among some of the wild fruits, yet they are not able to injure the larvæ in large fruits.

In Mexico an ichneumonid parasite infests the Morelos orange worm (*Trypeta ludens* Loew), namely, *Cratospila rudibunda* Say, though, as stated by Mr. Isaacs, not over from 10 to 15 per cent are parasitized. Prof. A. Berlese records *Hexamerocera brasiliensis* Ashm. MS. from the Mediterranean fruit-fly, and its use has been advocated by Von Ihering against *Trypeta ludens*.

PREVENTIVE AND REMEDIAL MEASURES.

The governments of certain countries have put in force regulations for the enforced control of fruit-flies, and in each instance the principle followed has been the inspection of orchards and cleaning up and destruction of all fallen fruits. This seems to be the plan principally recommended and relied upon for the control of this in-

sect, although as later mentioned other methods have been tried with more or less success.

In Mexico a grant of money was obtained for cleaning up orange orchards infested with the so-called orange worm (*Trypeta ludens*), and the following rules were issued by the Comision de Parasitología Agricola in whose hands the work was placed.

(1) Gather each day all mangoes, lemons, and oranges which may have fallen from the trees, and deposit them in a clean corner of the orchard.

(2) Destroy all fruit so accumulated at least once a week.

(3) It is preferable to destroy the fruit by burning, but it may be disposed of by burial, and when buried it should be covered with at least 50 centimeters (about 20 inches) of soil.

(4) If the same worm exists in the guava, this fruit should also be destroyed in the same manner.

Quarantine measures against oranges from Mexico have been in force for some years in California.

In Bermuda an act came into force in 1907 to improve fruit-growing conditions on the island by the suppression of the Mediterranean fruit-fly, and the work of eradication was placed in the hands of the board of agriculture. Concerning the scope and character of the work undertaken, Mr. Harris states:

The general plan has been to collect and destroy all the mature fruits of all kinds known to be punctured throughout the country; and in such cases, where trees bearing large numbers of small fruit are too numerous, about 90 per cent have been pruned back to prevent their producing fruit during the next fruiting season; by doing this it is possible to collect all the fruits produced by the trees that were left unpruned last season.

The fruits were collected in sacks, weighted by inserting a big stone before closing the bag, and thrown into the sea. In a few instances it proved more convenient to burn or boil the fruits.

The work was begun as soon as possible after the "Act" came into force. Ten sets of tools were purchased, and an inspector was appointed for each of the nine parishes, and the inspectors were supplied with laborers as necessity demanded.

No regulations appear to be in force in Mediterranean countries for the control of this or other fruit-flies, though a large reward is offered by the Italian Government for a remedy for the nearly related species, the olive fly (*Dacus oleæ* Rossi). No reference has been noted bearing on legislation along this line in Australia or in Cape Colony.

The regulation promulgated by the Hawaiian authorities to prevent the distribution of the insect from Oahu to other islands and the quarantine established by California against Hawaiian fruit have already been noted.

In regions where the pest is well established, as in Australia and South Africa, much attention has been given to devising effective remedies other than the collection and destruction of fallen fruit. A plan recommended by Lounsbury in 1898 was the covering of

trees with netting, and in the case of small to medium-sized trees the method was thought to be practical. Full directions were given for the employment of netting, and it was stated:

> The measure will undoubtedly be of great value to parties growing choice varieties in and about our villages where, because of laxity on the part of neighbors, the destruction of all maggot-infested fruit on one's place is unavailing as a preventive from further attack.

This plan, apparently, has not been followed to any great extent.

Professor Antonio Berlese, of Florence, Italy, began in 1903 tests of a poisoned bait against the olive fly (*Dacus oleæ*). The poisoned liquid was sprayed over the trees to destroy the adults which feed freely on available fruit juices and other sweetish substances. This work, commenced in 1903, was continued during 1905 and 1906. The material used consisted of honey 31 per cent, molasses 65 per cent, glycerine 2 per cent, and arsenite of potash 2 per cent. Prof. Berlese states:

> I have carried on the above experiments on 16,000 trees in three different localities, and have obtained absolute results, having succeeded in keeping sound, until they were ripe, all the olives on the trees which had been treated. This I did, although in the surrounding plantations all the olives were maggot-eaten and destroyed as early as September. Since the mixture is very soluble, the autumnal rains, which fall generally a little before the gathering of the fruit, are sufficient to wash off the poisoned substance, which was sprayed on to the olives. When, however, copious rains do not occur, it is necessary, before sending the olives to the press, to wash them in water in order to prevent any risk of poisoning.

In the Agricultural Journal, Cape of Good Hope, for December, 1904, Mr. C. W. Mally reports upon experiments, made quite independently of those of Prof. Berlese, in the destruction of the Mediterranean fruit-flies by a poisoned-bait spray, used with good results in his rearing cages. The bait consisted of a solution of 5 gallons of treacle (molasses), 1 pound of arsenate of lead, and 25 gallons of water. This poisoned bait was further tried out by Mally and others during several succeeding seasons, and in 1909 was put to practical field tests. Concerning the experiment Mr. Mally states:

> *Results.*—While the bait was expected to make a good showing in regard to the late varieties of fruit, its prompt effect in almost completely stopping the deposition of eggs in the fruit already ripening came as an agreeable surprise. The late maturing portion of the fruit on the trees, showing infestation to the extent of 50 per cent of the fruit in the proper stage of ripeness for the flies when the baiting began, came to maturity practically free from maggots—less than 1 per cent being infested. The fruit on all the late varieties of treated trees ripened perfectly, and was sold on the market and guaranteed free from maggots. No complaints of infestation were received at any time. On the control trees the situation was just the reverse, almost every ripe fruit being infested by maggots ranging from newly hatched to fully developed. Puparia were present under some of the decaying peaches, and there were numerous flies flitting about the trees.

The only explanation seems to be that the bait, being evenly distributed over the trees, prickly pears, bush, etc., around the orchard, was so easily available that practically all of the flies present during any one day found it very quickly, and fed on it to their destruction. It should be stated here that, even though the flies do not "drop dead" immediately after feeding on the bait, the poison begins to take effect in a very short time, and completes their destruction in about 24 hours. But during this time the flies, as indicated by specimens kept under observation in cages, are too sick to think of depositing eggs. The same fate evidently awaited the fresh flies as they emerged from the ground. The fact that they must feed for a number of days before the eggs are sufficiently mature to be deposited gives ample time for them to find the bait.

If any of the flies that emerged from the mass of infested fruit under the control trees found their way to the treated orchard they must have found the bait at once on arrival and died without depositing eggs. This shows that either the flies ordinarily do not travel over a space of 400 yards or else they find the bait so quickly that there is nothing to fear from them. This also has an important bearing on the question of contamination coming from neglected orchards, for it indicates that the progressive fruit grower will reap the full benefit of his care in treating his trees, even though his neighbor's orchard, or the native bush near by, is full of flies.

In these tests in 1909 the formula used was sugar 3 pounds, arsenate of lead 4 ounces, water 5 gallons. Rains interfere much with the use of the spray and applications must be repeated to maintain it on the trees. A total of 14 applications was made from January 15 to March 20, the expense for material being about 8 cents per tree. The poisoned-bait method of controlling this and other fruit-flies would appear entirely feasible, especially in more or less arid regions, where the spray would not be washed off by rains. On the other hand, the application of the spray to fruit just as it is approaching maturity might prove objectionable. The poisoned-bait method is already being tested in the United States for the control of the apple maggot. The results of this work, so far as the writer is aware, have not been indicated.

Considerable interest was aroused in the so-called paraffin remedy, first developed in West Australia, which consists in trapping the adult flies with kerosene oil. The oil is said to be particularly attractive to flies, and the vessels containing kerosene are placed in the forks of the tree and attract them to their death in considerable numbers. It has been found, however, that a large proportion of the insects thus trapped are males, and practical tests of the method by Lounsbury showed that little, if any, protection to the fruit resulted.

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Approved:

JAMES WILSON,
Secretary of Agriculture.

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